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INFORMATION CIRCULAR

ACCIDENT EXPERIENCE

IRON-ORE MINES - LAKE SUPERIOR DISTRICT

1940-45

BY

FRANK E. CASH

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ACCIDENT EXPERIENCE IRON-ORE MINES - LAKE SUPERIOR DISTRICT 1940-45[1]

By Frank E. Cash[2]

CONTENTS

	Page
Introduction	1
Acknowledgments	2
Mining methods	2
Injury experience	2
Table 1. - Accident data, all mines, 1940-45	3
Table 2. - Comparison of frequency and severity of accidents in iron-ore mines, 1940-45	4
Table 3. - Accident data, by methods, all mines, 1940-45	4
Table 4. - Accident disabilities, 1940-45	5
Table 5. - Accidents by years, divided as to causes and types of operations, 1940-45	6
Table 6. - Severity of injuries by causes, 1944-45	8
Summary	9

INTRODUCTION

The iron-ore ranges in the Lake Superior district are the Marquette in Michigan, Menominee and Gogebic in Michigan and Wisconsin, and the Cuyuna, Mesabi, and Vermilion in Minnesota. These ranges produce about 85 percent of the iron ore mined in the United States. Accident experience in connection with this production is better than that of the regions producing the remaining 15 percent. Production and shipments vary slightly from year to year but closely approximate each other over a period of years.

This information circular supplements, continues, and combines the data in Information Circular 7321,[3] including figures of 1944 and 1945.

During the 6-year period 1940 to 1945, inclusive, 481,485,475 long tons of iron ore was shipped from the Lake Superior district.[4] Michigan and

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1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7410."

2/ Supervising engineer, Bureau of Mines, Duluth, Minn.

3/ Cash, Frank E., and Larsen, Reuben D., Accident Experience, Iron-Ore Mines - Lake Superior District, 1940-43: Bureau of Mines Inf. Circ. 7321, 1945, 9 pp.

4/ Tonnage figures from Lake Superior Iron Ore Association.

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Wisconsin shipped 93,787,648 tons, or 19.5 percent of the total, and employed annually an average of approximately 14,300 men; Minnesota shipped 387,697,827 tons, or 80.5 percent, and employed annually an average of approximately 9,300 men. The tons produced per man employed is much greater in Minnesota than in Michigan and Wisconsin, owing to the large open-cut production in Minnesota.

ACKNOWLEDGMENTS

This consolidated report was made possible through the cooperation of the operating companies in furnishing their annual injury data for use at the Lake Superior Mining Section, National Safety Council annual meetings, and to them the author expresses appreciation. These data were first compiled and presented in 1941 to cover the 1940 experience.

MINING METHODS

In Minnesota, most of the ore is produced from open cuts. In Michigan and Wisconsin, the mining methods used, in the order of their relative production, are top slicing, sublevel caving, and stoping. Only a small tonnage of ore is mined from open cuts in Michigan and Wisconsin.

The average number of operating mines in the district during the 6-year period was 120, of which 71 were open-cut and 49 underground operations. Eighteen of the underground mines employ the top-slicing method of mining, 15 sublevel caving, and 16 stoping.

INJURY EXPERIENCE

These injury data were largely taken from those furnished by the operating companies and were assembled and published by the Lake Superior Mining Section of the National Safety Council.5/ However, they are supplemented, for the purpose of comparison, by figures published by the Bureau of Mines in the reports of the National Safety Competition and Annual Surveys of Metal Mine Accidents.6/ This discussion of the data is based entirely upon observations and opinions of the author.

During the period from 1940 to 1945 inclusive, increased production was necessary irrespective of manpower. Although there was no acute shortage of men, the Armed Services took many experienced men, necessitating their replacement by men with less experience. The combination of circumstances had, and continues to have, a definite effect upon injury experience.

Table 1 gives (by years and totals for all mines) the shipments, man-hours worked, days lost as a result of injuries, fatal and total permanent-disability injuries, partial permanent disability injuries, and temporary injuries, with frequency and severity rates for the 6-year period.

5/ Percy A. Carmichael (1941 and 1942 proceedings), Reuben D. Larsen (1943 and 1944 proceedings), and Reuben D. Larsen, Stanley A. Mahon, and George A. Borgeson (1946 proceedings), Lake Superior Mining Section, National Safety Council.

6/ W. W. Adams, Forrest T. Moyer, and others.

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TABLE 1. - Accident data, all mines, 1940-45

Year	Gross tons shipped	Man-hours worked	Days lost account accidents	Fatal	Partial permanent	Tempo-rary	Fre-quency	Sever-ity
1940	63,948,846	31,217,310	139,303	*17	7	359	12.27	4.46
1941	80,747,859	41,239,423	200,114	25	13	515	13.41	4.85
1942	93,008,726	45,912,672	264,701	34	12	745	17.23	5.76
1943	85,962,168	51,863,102	273,157	*34	25	1,035	21.09	5.27
1944	81,857,005	42,023,601	180,368	*21	29	878	22.08	4.29
1945	75,960,871	40,010,662	201,365	*25	29	808	21.54	5.03
	481,485,475	252,266,770	1,259,008	156	115	4,340	18.28	4.99

*Includes 1 total permanent disability.

The frequency rate is the number of lost-time injuries per million man-hours worked, and the severity rate is the number of days lost because of injuries per thousand man-hours worked. A lost-time injury is considered to be one that caused loss of time beyond the day or shift on which the injury occurred. In calculating severity, temporary disabilities are weighted according to the actual calendar days of disability, including holidays and Sundays, whereas deaths and permanent injuries are weighted according to the United States Bureau of Mines "Scale of Time Losses for Weighting Deaths and Permanent Injuries," adopted from the American Standards Association.

Production increased during the first 3 years and decreased during the last 3 years. Man-hours worked increased during the first 4 years and decreased during the last 2 years. Frequency increased for 5 years, with a slight decline in 1945, whereas severity increased during the first 3 years, declined for 2 years, and increased again in 1945. During the 6-year period there were 152 fatalities, 4 permanent total-disability injuries, 115 partial-permanent injuries, and 4,340 temporary disabling injuries; these are tabulated and discussed as to causes, types of operations, and methods of mining. Of the 156 fatal and total disability injuries, falls and slides of ground were responsible for 70, or 44.9 percent; haulage injuries (belt, truck, and locomotive) were next in number, 13, or 8.3 percent of the fatal and total-disability injuries. Other causes, in the order of the resulting injuries, were: Persons falling (shafts, raises, banks, scaffolds, etc.), 9; explosives, 8; railroad cars and locomotives, 7; falling material (shafts, raises, etc.), 7; machinery (moving), 6; loading equipment (shovels, scrapers, etc.), 6; electricity (shocks and burns), 5; cages, skips, and buckets, 4; persons falling (slipping and stumbling), 4; suffocation (natural gases), 3; handling material, 2; runs of ore and rock (chutes and bins), 2; drilling equipment, 2; falling material (other than ground), 1; inrushes of mud and water, 1; not classified, 6.

For the 6-year period there was one fatal or total permanent injury for each 3,086,445 tons shipped, one partial permanent disability for each 4,186,830 tons, and one temporary disability for each 110,941 tons shipped. For each fatal or total permanent injury there were 0.74 partial-permanent and 27.82 temporary-disability injuries.

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As a means of comparison, table 2 lists the frequency rate for the iron-ore mines in the United States, the frequency and severity rates for the metal mines entered in the National Safety Competition conducted by the United States Bureau of Mines, and the iron-ore mines in the Lake Superior district for the years 1940 to 1945, inclusive.

Table 3 gives accident data (including totals and combined figures) for the 6-year period, by years, in the Lake Superior district, divided as to type of operation.

TABLE 2. - Comparison of frequency and severity of accidents in iron-ore mines, 1940-45

Year	Iron-ore mines, United States, frequency	Metal-mines entered in National Safety Competition		Iron-ore mines Lake Superior District	
		Frequency	Severity	Frequency	Severity
1940	19.63	14.47	6.09	12.27	4.46
1941	23.08	20.14	6.85	13.41	4.85
1942	24.41	20.62	5.55	17.23	5.76
1943	25.57	24.21	6.27	21.09	5.25
1944	24.78	25.42	5.70	22.08	4.29
1945		31.36	7.35	21.54	5.03

TABLE 3. - Accident data, by methods, all mines, 1940-45

Type of Operation	Man-hours worked	Days lost	Fatal	Partial permanent	Temporary	Frequency	Severity
Miscellaneous development	387,178	214	0	0	3	7.72	0.55
General shops ...	20,754,936	30,933	4	4	106	5.45	1.09
Open cuts and concentrator plants	93,979,019	381,650	45	47	1,005	10.61	4.06
Top slicing	54,819,381	395,558	34	22	1,325	25.19	5.39
Stoping	29,296,452	179,841	24	19	589	20.15	6.15
Sublevel caving..	53,029,804	370,812	49	23	1,312	26.09	6.99
All operations..	252,266,770	1,259,008	156	115	4,340	18.28	4.99

Although all injuries are potentially serious, and their occurrence must be decreased to improve accident experience, once an injury is received, the lost time, suffering, reduction in production, and expense are largely reflected in severity rather than in frequency.

For comparison in this report, since the injuries have occurred, severity is used for the weighting figure.

Under "type operations," "miscellaneous development" is all underground work and includes prospecting, extensive rock drifting, and shaft sinking, and raising. "General shops" are those doing the general repair work for a

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group of mines. In most instances the shop experience is included with the individual mine. "Open cuts and concentrator plants" cover the open-cut mines and their concentrating plants, whether the plants are locally or centrally located and operated. "Top slicing", "stoping", and "sublevel caving" are the various methods of mining used underground.

As shown, the most hazardous type of operation is sublevel caving, in which both frequency and severity rates are higher than in other operations. Although limited in extent, "miscellaneous (underground) development" is shown as having the best experience. The frequency and severity rates for all operations in the region for the 6 years are favorable when compared with other iron-ore and metal-mine operations in this country.

In table 4, the injuries are listed under the various type of operations, and the average length of disability per injury is shown for each type of operation.

TABLE 4. - Accident disabilities, 1940-45

Operation	Fatals*			Partial permanent*			Temporary		
	Number accidents	Total days lost	Average days lost	Number accidents	Total days lost	Average days lost	Number accidents	Total days lost	Average days lost
Miscellaneous development	0	-	-	0	-	-	3	214	71.3
General shops	4	24,000	6,000	4	2,156	539.0	106	3,717	35.1
Open cuts and concentrator plants.....	45	270,000	6,000	47	63,166	1,344.0	1,005	47,707	47.5
Top slicing..	34	204,000	6,000	22	24,282	1,103.7	1,325	67,264	50.8
Stoping.....	24	144,000	6,000	19	13,406	705.6	589	24,000	40.7
Sublevel caving.....	49	294,000	6,000	23	23,514	1,022.4	1,312	54,105	41.2
All operations..	**156	936,000	6,000	115	126,524	1,100.2	4,340	197,007	45.4

* Weighted disabilities.
**Includes 4 permanent total disabilities.

Table 5 lists fatal and permanent-total, permanent-partial, and temporary disabling injuries by causes for all mines, also the total injuries for the period 1940 to 1943, the injuries for the years 1944 and 1945, and the totals for the 6-year period. There are differences in company methods of investigating and compiling these data; and although certain local procedures answer the purposes of the individual company, it is often difficult to classify an injury as to its cause. A number of the injuries listed as unclassified would probably fall in one of the other classifications, had the descriptions been more specific and complete. This table gives a complete detailed picture of the injruies by classes and their causes under the various type operations for the 6-year period.

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TABLE 5. - Accidents, by years, divided as to causes and types of operations, 1940-45

Causes		Miscellaneous development			General shops			Open cuts and concentrators			Top slicing			Stoping			Sublevel caving			All operations			Totals
		Total 1940-43	44	45	Total 1940-43	44	45	Total 1940-43	44	45	Total 1940-43	44	45	Total 1940-43	44	45	Total 1940-43	44	45	Total 1940-43	44	45	1940-45
Falls and slides of ground	F							7	1		13	4	5	9	2	1	20	5	3	49	12	9	70
(ore and rock)	PP												1	2	1		2	3		4	4	1	9
	T							12	1		159	58	38	51	12	6	156	55	45	378	126	89	593
Haulage	F						1	5	1	1			1	1			2	1		8	2	3	13
(belt, truck and locomotive)	PP							1	1	1	1		1	1	1		2		1	5	2	3	10
	T							47	36	15	20	24	11	19	10	9	32	13	18	118	83	53	254
Explosives	F							1			1				1		4		1	6	1	1	8
	PP										1						3			4	0	0	4
	T							4	1	1	6	1	1			1	5	3		15	5	3	23
Machinery	F				1			3	1					1						5	1	0	6
(moving)	PP				2			2		7	2	1	2	1	1			1	3	7	3	12	22
	T				4	1		18	6	4	13	7	5	15	1		27	4	5	77	19	14	110
Loading equipment	F							3		1	1						1			5	0	1	6
(shovels, scrapers, etc.)	PP							2	2	2	1						2			5	2	2	9
	T							23	8	9	18	11	6	7	3	1	17	6	4	65	28	20	113
Persons falling	F						1	1		2	1	1		1			2			5	1	3	9
(shafts, raises, banks,	PP																			0	0	0	0
scaffolds)	T						3	6	11	3	9	8	6	22	6	6	14	9	13	51	34	31	116
Railroad cars and locomotives	F				1			3		2							1			5	0	2	7
	PP							6												6	0	0	6
	T							9		6			3	2					1	11	0	10	21
Persons falling	F							4												4	0	0	4
(slipping and stumbling)	PP											1								0	1	0	1
	T				3	1	3	58	15	13	66	15	9	12	9	4	33	6	5	172	46	34	252
Falling material	F									1	3				1		1		1	4	1	2	7
(shafts, raises, etc.)	PP														1		1			1	1	0	2
	T								3	1	13	22	25		13	5	7	20	23	20	58	54	132
Electricity	F							2			1			1				1		4	1	0	5
(shocks and burns)	PP							1												1	0	0	1
	T							1	1	1			1	6			1	1		8	2	2	12
Suffocation	F													1			2			3	0	0	3
(natural gases)	PP																			0	0	0	0
	T							11						1						12	0	0	12
Cages, skips, and buckets	F													2			1		1	3	0	1	4
	PP									1					1	1				0	1	2	3
	T									1		1	2	8		1	2	1	7	10	2	11	23

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TABLE 5. - Accidents, by years, divided as to causes and types of operations, 1940-45 (Continued)

Causes		Miscellaneous development			General shops			Open cuts and concentrators			Top slicing			Stoping			Sublevel caving			All operations			Totals
		Total 1940-43	44	45	Total 1940-43	44	45	Total 1940-43	44	45	Total 1940-43	44	45	Total 1940-43	44	45	Total 1940-43	44	45	Total 1940-43	44	45	1940-45
Handling material	F							1									1			2	0	0	2
	PP				1	1						2	1		3					1	6	1	8
	T					4	6	14	29	17	49	71	32	36	22	5	54	41	44	153	167	104	424
Runs of ore and rock (chutes and bins)	F										1			1						2	0	0	2
	PP																			0	0	0	0
	T											9		8	2		4	3		12	14	0	26
Falling material (other than ground)	F										1									1	0	0	1
	PP							2	1		1									3	1	0	4
	T				1			14	7	2	39	11	6	5	7	2	17		3	76	25	13	114
Drilling equipment	F							1							1					1	1	0	2
	PP							2	2	2	3			2						7	2	2	11
	T				3	1			14	9		2	11	1	3	7	3	8	13	7	28	40	75
Flying objects	F																			0	0	0	0
	PP							5	2		4			1	1		1	2	1	11	5	1	17
	T				1	3		11	6	3	13	6	6	12	9		27	4	5	64	28	14	106
Hand tools	F																			0	0	0	0
	PP							2							1				1	2	1	1	4
	T				5	2	2	18	5	8	14	15	5		3	5	7	7	15	44	32	35	111
Mine fires	F																			0	0	0	0
	PP																			0	0	0	0
	T																5			5	0	0	5
Inrushes, mud and water	F											1								0	1	0	1
	PP																			0	0	0	0
	T											3	2							0	3	2	5
Not classified	F							3		1						1			1	3	0	3	6
	PP									3						1				0	0	4	4
	T	3			60		3	370	81	72	361	19	93	144	27	61	418	51	50	1,356	178	279	1,813
Totals	F	0	0	0	2	0	2	34	3	8	22	6	6	17	5	2	35	7	7	110	21	25	156
	PP	0	0	0	3	1	0	23	8	16	13	4	5	7	10	2	11	6	6	57	29	29	115
	T	3	0	0	77	12	17	616	224	165	780	283	262	349	127	113	829	232	251	2,654	878	808	4,340
Grand total		3	0	0	82	13	19	673	235	189	815	293	273	373	142	117	875	245	264	2,821	928	862	4,611

F - Fatal and permanent total.
PP - Partial permanent.
T - Temporary disability.

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Aside from the "not-classified" injuries, there are 20 listed causes of the injuries. Falls and slides of ground caused the greatest number of fatal and temporary-disabling injuries. Haulage came next as a cause of fatal injuries; but injuries due to handling material ranked second in total number.

In table 6 the list of causes used in table 5 are arranged in order of the severity of injuries.

TABLE 6. - Severity of injuries by causes, 1944-45

Causes	Number of injuries	Days lost	Days lost per injury
Falls and slides of ground	10	12,873	1,287.3
Haulage	5	6,054	1,210.8
Explosives	6	6,542	1,090.3
Machinery	12	12,387	1,032.3
Loading equipment	241	144,169	598.2
Persons falling. (Shafts, raises, banks, scaffolds.)	17	7,964	468.5
Railroad cars and locomotives	49	19,573	399.4
Persons falling. (Slipping and stumbling.)	69	27,432	397.6
Falling material. (Shafts, raises, etc.)	146	39,175	268.3
Electricity	48	10,409	216.9
Suffocation	116	23,281	200.7
Cages, skips, and buckets	53	10,000	188.7
Handling material	73	11,640	159.5
Runs of ore and rock	39	4,255	109.1
Falling material. (Other than ground.)	464	27,867	60.1
Drilling equipment	278	12,496	44.9
Flying objects	69	2,914	42.2
Hand tools	81	2,424	29.9
Mine fires	14	332	23.7
Inrushes, mud, and water	No injuries.		
Not classified	No injuries.		
All causes	1,790	381,787	213.3

Explosives and electricity caused relatively few injuries, but the former caused the greatest number of days lost per injury, 1,287.3, and electricity was a close second with 1,210.8 days lost time per injury. Inrush of mud and water, and railroad cars and locomotives, in their order, were next, with 1,090.3 and 1,032.3 days lost per injury, respectively. Next came falls and slides of ground with 598.2 days lost; cages, skips and buckets, 468.5; moving machinery, 399.4; persons falling (shafts, raises, banks, scaffolds, etc.), 397.6; haulage, 268.3; and flying objects, 216.9 lost-days per injury. The remainder of the causes show fewer days lost-time than the average of 213.3 days from all causes. During the 2-year period covered by

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this table there were no injuries caused by mine fires and suffocation (natural gases).

SUMMARY

On an average, 120 iron mines are operated by 26 companies in the Lake Superior district, which annually produce 85 percent of the iron ore mined in the United States. Individual open-cut mines produce and ship 20,000 to 20,000,000 tons annually, and the underground mines from 100,000 to 1,000,000 tons a year.

The injuries in the district, although relatively fewer and less severe than in other metal-mining districts, have increased in frequency during 5 years of the 6-year period and have declined slightly for 1945. Severity increased the first 3 years, decreased during the next 2 years, and increased during 1945.

"Miscellaneous development", usually considered hazardous work, although covering the relatively small number of 387,178 man-hours of exposure, occasioned only three lost-time injuries, which resulted in 214 days of disability; the injury rates for the 6 years were: Frequency, 7.72 and severity, 0.55.

"General shops" cover a total of 20-3/4 million man-hours of work, with 114 injuries divided as follows: 4 fatal (1 total permanent disability), 4 partial permanent, and 106 temporary disabilities. The frequency rate increased from 1.63 in 1940 to a total 6-year rate of 5.45. The trend of severity was upward, from 0.03 in 1940 to 4.37 in 1945 and 1.09 for the 6-year period.

Under "open cuts and concentrator plants", the hours worked increased in 1940, 1941, 1942, and 1943 and declined 16-3/4 million man-hours in 1944 and 1945. There was an increase in frequency and severity rates for the first half of the 6-year period and a decrease during the last half. The resulting frequency figures are as follows: 1940, 6.88; 1943, 14.82; 1945, 11.18; and for the 6-year period, 10.61. The severity figures are: 1940, 2.65; 1942, 6.03; 1944, 2.05; 1945, 4.20, and for the period, 4.06. The trend of both rates is upward.

Under "top slicing", the hours worked increased for 3 years and decreased the last 3 years. The frequency rate increased annually and in 1945 was 2.3 times that of 1940, with the 6-year frequency rate of 25.19. The severity rate was erratic, ranging from a low of 4.23 in 1943 to a high of 6.89 in 1945, and the 6-year figure is 5.39.

With "stoping", the hours worked increased and decreased with production, as they did in "top slicing." The frequency rate increased from 11.59 in 1940 to 26.89 in 1944 and showed a slight improvement in 1945.

The frequency figure for the 6-year period was nearly double that of 1940, or 20.15. The severity rate was irregular, with a low of 1.08 in 1941, a high of 11.44 in 1943, and for the 6-year period the severity rate was 6.15.

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Under "sublevel caving", the hours worked have ranged from 8 to 9-1/2 million per year, with the highest figure in 1941 and the lowest in 1944. The frequency and severity figures have been and are higher than those for the other operations. The frequency rate increased annually from 18.61 in 1940 to 30.47 in 1945, with a total average for the 6-year period of 26.09. The severity rate reached a high of 9.40 in 1941 and a low of 5.20 in 1943, with the total average figure of 6.99.

Over 481 million tons of ore was shipped and 252 million man-hours were worked during the 6-year period in all operations. The over-all frequency rate increased from 12.27 in 1940 to 22.08 in 1944 and declined to 21.54 in 1945, with a 6-year figure of 18.28. The low severity figure was 4.29 in 1944, the high was 5.76 in 1942, and for the 6-year period the severity rate was 4.99.

Most of the mines are highly mechanized, and during the past 6 years produced increased tonnages of iron ore, maintaining old equipment in relatively good repair but with a minimum of replacements or new equipment.

Electric cap lamps are furnished and used in virtually all of the underground mines. Employees are required to wear hard hats, safety-toe shoes, and safety goggles for certain classes of work in or around all mines.

With the exception of the very small producers, the companies maintain safety departments with safety supervisors, engineers, and inspectors.

Most of the companies operating underground mines maintain mine-rescue equipment and personnel trained in its use.

Previous to 1940, most of the companies encouraged and sponsored first-aid training for their employees, and a number of them had 100 percent employee first-aid training. Since 1940, very little first-aid training has been done in the district.

Most companies have some form of printed or mimeographed operating and safety rules. Most open-cut mines require wearing protective shoes or boots in summer but in severely cold weather allow their employees to discontinue the practice. Protective hats are worn in all underground and some open-cut mines.

A number of companies provide goggles, and some issue the corrective-vision type. A few companies require their use throughout the shift for all employees but many leave it up to the individual to wear them when necessary, or leave it to the supervisory force to require their use for selected types of work.

All main haulage underground is done with electric locomotives, a few of which are storage-battery types. There are in use a few chute-to-drift flight conveyors. Haulage in open-cut mines is by belt, electric and steam locomotives, and trucks.

About half of the underground mines maintain stench-warning systems for emergency use, such as in case of mine fire or flood.

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Blast-hole drilling in open-cut mines is done largely by electrically operated well- or wagon-type drills, with a few gasoline or electrically operated auger-type drills for soft material. In underground mines, compressed-air-operated percussion-type drills are generally used, with a few rotary auger-type drills for soft material and electrically driven rotary core drills for deep holes or very hard material.7/ Virtually all drilling is done wet.

In open-cut mines, blasting is done with dynamite and some "nitramon" detonated with electric blasting caps or electric blasting caps and detonating fuse. The explosive in use underground is dynamite with fuse and detonators. In extremely wet places, shaft sinking, and heavy blasting a limited amount of blasting is done electrically. The magazines, largely underground, for the storage of explosives, usually are of good construction, safely located, and well-ventilated.8/

Most of the underground mines have two or more openings and are ventilated mechanically. A few mines have excellent ventilation systems, with provisions for heating air in cold weather; others are not so well ventilated. Periodic dust surveys are made in most of the mines, and remedial procedures are instigated promptly if dust counts exceed a recognized safe limit.

The surface plants, old and new, are well arranged and maintained. Most of the new plant structures are of modern design and construction. The trend is to house all, or virtually all, necessary surface units in one building. The newer change houses are spacious and air-conditioned and are provided with bathing and toilet facilities and separate rooms for street and mine clothes.

In general, a determined effort is being made by the mining companies and their employees in the Lake Superior district to decrease the occurrence of injuries incurred in mining iron ore. Compared to other metal mines in this country, the injury experience in the Lake Superior district is favorable, but it can and should be improved; improvement can be realized by closer coordination of effort by employees and management.

7/ Johnson, Ernest W., and Cash, Frank E., Diamond Drilling of Blast Holes, Lake Superior District Iron Ore Mines: Bureau of Mines Inf. Circ. 7317, 1945, 11 pp.

8/ Cash, Frank E., Storage of Explosives in Underground Mines of the Lake Superior District: Bureau of Mines Inf. Circ. 7343, 1946, 9 pp.

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